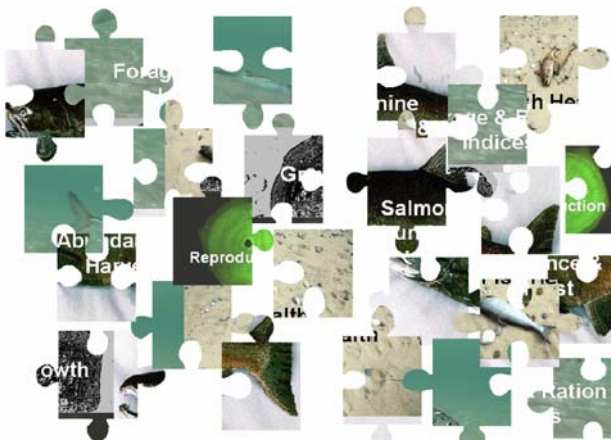


Great Lakes Fishery Commission  
Lake Michigan Committee Meeting  
Niagara Falls, Ontario  
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# Status of Salmonines in Lake Michigan, 1985-2007



## Report from the Salmonid Working Group to the Lake Michigan Committee

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## Introduction

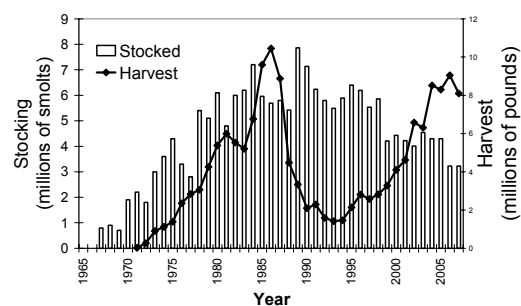
Salmonines play an important role in the Lake Michigan ecosystem. In particular, Chinook salmon *Oncorhynchus tshawytscha* were introduced in 1967 to help control exotic forage fishes such as alewife *Alosa pseudoharengus* and rainbow smelt *Osmerus mordax*. Chinook salmon populations now support a valuable fishery and significantly suppress alewife populations. The overall fisheries management goal established for Lake Michigan in the Fish-community Objectives (FCO) is to restore and maintain the biological integrity of the fish community so that production of desirable fish is sustainable and ecologically efficient (Eshenroder et al. 1995). The salmonine objective specifies establishment of a diverse salmonine community capable of sustaining an annual harvest of 2.7 to 6.8 million kg, of which 20-25% is lake trout.

Inherent in this objective is the desire to maintain a salmonine community dominated by Chinook salmon (i.e., target annual yield of 3.1 million kg) in sufficient abundance to suppress alewife populations but not beyond levels where predator consumption would threaten food web integrity. The Salmonine and Planktivore Objectives are based on the understanding that large populations of exotic forage fishes, such as alewife and rainbow smelt, negatively impact recruitment of native fishes, and that controlling exotic forage fishes presents an opportunity to create new, diverse fishing opportunities. Therefore, progress toward these objectives is evaluated by determining the relative balance between predator and prey (e.g.,

Chinook salmon and alewife interactions) rather than suppression of alewife through extreme top-down predation.

Chinook salmon stocking levels were highly correlated with harvest in the first two decades of stocking. There was a disparity between stocking and harvest even with sustained stocking rates during the late-1980s. More recently, it is apparent that trends in harvest are no longer related to stocking alone (Figure 1).

Figure 1. Chinook salmon stocking and harvest



Chinook salmon experienced a noticeable disease epizootic and significant decline in abundance, possibly resulting from an increase in natural mortality brought on by nutritional stress, in 1987-88. In 1999, Chinook salmon stocking was reduced in hopes of minimizing risk to the fishery associated with instability in Chinook salmon survival (Figure 1). Through the Lake Michigan Technical Committee process, a Salmonid Working Group (SWG) was established to evaluate the effects of the stocking reduction and to identify indicators useful in the early detection of future Chinook salmon population stress; these indicators were originally referred to as the “10 Red Flags”.

The purpose of the SWG is to cooperatively collect and disseminate knowledge regarding Lake Michigan salmonines and to assess the status of pelagic salmonines and their prey (Terms of Reference for the Salmonid Working Group 2008). The SWG's main goal is to evaluate progress toward meeting the Salmonine FCO aimed at maintaining a diverse salmonine community. Currently, the SWG implements and continues to develop a science-based approach (i.e., Red Flags) for annually evaluating measurable indices of the salmonine population, and recommends changes in management, if necessary, based on the results of the Red Flags analysis. This approach, combined with consultation with managers and constituents, has resulted in two (1999 and 2006; Figure 1) approximately 25% lakewide stocking reductions of Chinook salmon.

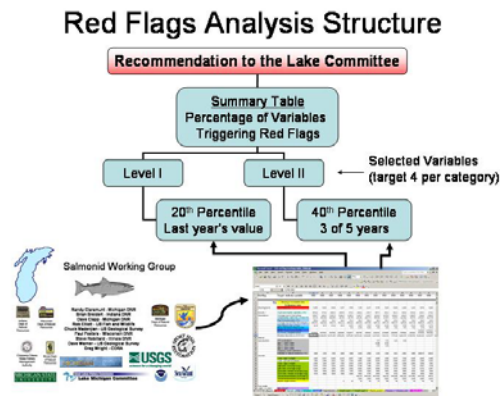
## Methods

The SWG uses a set of criteria to measure the health of the Chinook salmon population and evaluate potential threats to predator-prey balance. The biological criteria utilize all currently available data from ongoing assessments, including: estimates of **abundance** from creel and fishery-independent surveys, records of stocking and estimates of **natural reproduction**, estimates of size at age and **growth**, trends in **ration and forage fish** abundance, and indices of **fish health**. For each biological category, we have several indices available for analysis. However, we have selected only a few representative parameters from each category to present here. We used the frequency distributions of these variables to indicate when values for the current

year (Level I) or three of the previous five years (Level II) are outside an acceptable range.

- **Level I:** A value from the most recent year of data that is lower than the 20<sup>th</sup> or higher than the 80<sup>th</sup> percentile will trigger a red flag.
- **Level II:** Values from three out of the last five years which are lower than the 40<sup>th</sup> or higher than the 60<sup>th</sup> percentile will trigger a red flag.

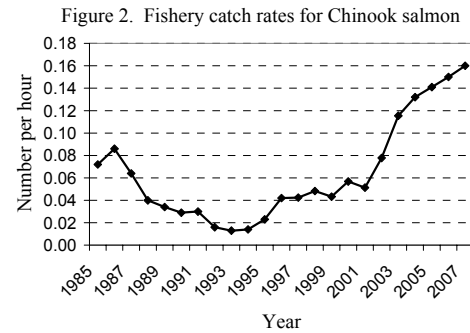
If more than 50% of the variables for either level indicate red flags, the SWG will make a recommendation to the Lake Michigan Committee to consider revising management actions (e.g. – stocking rates, fishery regulations) for salmonines in Lake Michigan.



The data included in this report are provided by several agency and university sources (see diagram above). Members of the SWG assist in the collection and/or consolidation of such data by providing summary statistics in a lakewide time-series table. The data table covers 1985-present and is focused on Chinook salmon (and their prey) as indicators of overall predator-prey balance; however, there are years with missing values where data were either not collected or are not yet available.

## Results and Discussion

**Abundance:** Harvest, catch rates, survey CPEs, and periodically-estimated standing stock size (catch-at-age analysis) are utilized to evaluate trends in abundance. Lakewide harvest was highest in the late 1980s, declined substantially during 1989-1994, and has been increasing since 1995 (Figure 1). The estimated harvest for 2007 was approximately 3.7 million kg, which is a decrease from 4.1 in 2006. Annual lakewide harvest has ranged from 0.6-4.7 million kilograms (kg) with an average ( $\pm$ SE) harvest of  $2.3 \pm 0.3$  million kg (Table 1). Similarly, catch rates in the recreational fishery declined in the late 1980s, were low during 1992-1994, but have been rising since 1995. Average catch rate over the entire time series is  $6.4 \pm 1.0$  and ranged from 1.3 – 16.0 fish per 100 hours of fishing (Table 1). In 2007, catch rates are at all-time high levels (16.0 fish per 100 hours) and these extremely high catch rates (Figure 2) may be indicative of unusually high densities of Chinook salmon, low prey abundance, or a combination of both. Similar to recreational catch rates, survey CPE increased from 2003 to 2005, but since 2006 survey CPE has been decreasing. CPE in 2007 (2.11 fish per 1,000 ft per 4 hour set) declined and was below the average CPE of 2.6 (Table 1). The decrease in survey CPE is likely the result of fewer age 0 and 1 year olds being recruited into the population and may be indicative of declines in Chinook salmon stocks in the near future. Recreational fishery catch rates triggered a level I red flag, and all abundance variables (i.e., harvest, fishery catch rates, and survey CPE) triggered level II red flags (Table 1).

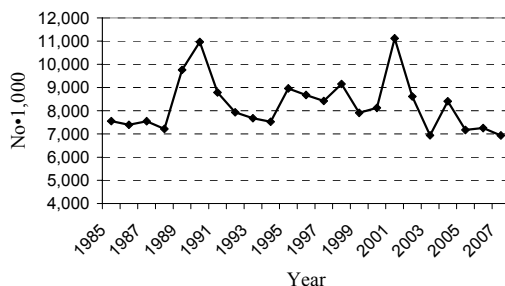


**Reproduction:** Recruitment of naturally-produced Chinook salmon smolts has increased since their introduction in 1967. Natural reproduction has been estimated periodically throughout the period 1985-2007, and estimates in the early 1990s from oxytetracycline (OTC) studies suggested that natural recruitment accounted for 29-35% of lakewide adult stocks when stocking levels were near their highest (6-7 million smolts; Figure 1 and 3).

Estimates for 2001-2003 from OTC-marked fish collected in 2004 and, more recently, estimates from the lakewide OTC evaluation starting with the 2007 year-class (Claramunt et al. 2007) indicate that wild fish recruitment has increased such that natural recruits now account for approximately 54% of the lake population (Table 1), which is higher than the average of 43.3%. However, total recruitment (wild and hatchery recruitment combined) has declined to 6.9 million smolts, in part because of management strategies aimed at lowering stocking rates and reducing total Chinook salmon abundance (Figure 3). Because the total number of Chinook salmon recruits entering the lake is at all-time lows (since 1985), and contribution from wild production has been high and variable, both variables triggered level II red flags. Only total

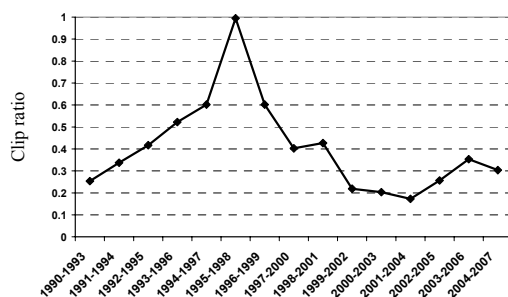
recruitment triggered a level I red flag (Table 1).

Figure 3. Total Chinook salmon recruitment



Individual stream estimates of smolt production are not available for 2007, but we were able to utilize (for the Red Flags analysis) a ratio of the percentage of marked fish (i.e., any fin clip) in the open-water survey to the percentage of marked fish stocked as another indicator of recruitment. The proportion of natural recruits in the lake increases as the clip ratio approaches zero (Figure 4). Three year averages were used to reduce variability in the analysis. The clip ratio triggered a level II red flag, suggesting that natural recruitment in recent years has been relatively high (Table 1).

Figure 4. Observed vs. expected fin clip ratio



**Growth:** Several weight-at-age indices suggest that growth conditions have changed over time, presumably from changes in Chinook salmon abundance, forage levels, and environmental factors (Figures 5 and 6).

Figure 5. Chinook salmon weight-at-age 2

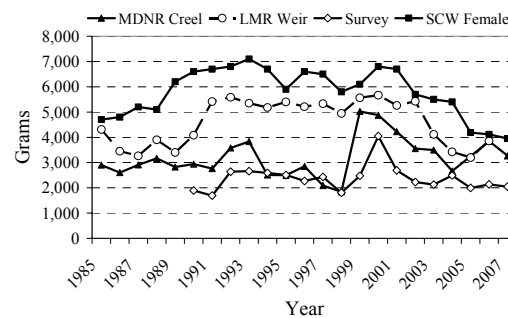
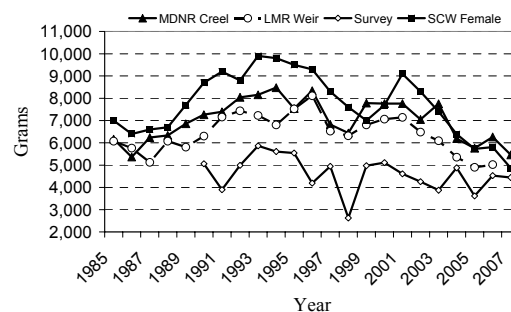


Figure 6. Chinook salmon weight-at-age 3

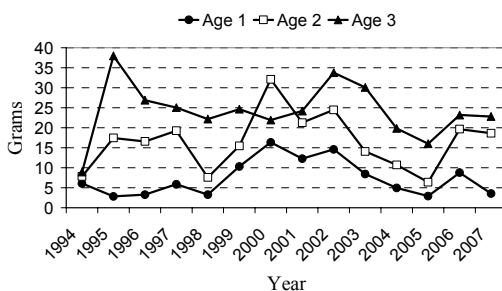


For this report, we selected Chinook salmon weight at age-2 from the open-water survey (male and female combined), weight at age-3 (female) from Strawberry Creek (WI) weir returns, standard weight index from Strawberry Creek weir, and weight at age-3 from the recreational fishery to assess changes in growth (Table 1). Chinook salmon were sampled during June and July in the open-water survey; weir return data were collected in September. We chose these sources of growth data because they are collected over a relatively short time period, collected during two different seasons, and the large sample sizes reduce variability in size-at-age estimates. Most of the data sources indicate that weight at age peaked in 2000-2001, following the production of an abundant year-class of alewife in 1998. Average weight at age-2 from the open-water survey was  $2,357 \pm 104$  grams (g) and ranged from 1,692-4,049 g throughout the time series

(Figure 5; Table 1). Age-2 fish in 2007 weighed 2,047 g, which was down from 2006 and smaller than average (Table 1). In 2007, weight of age-3 Chinook salmon at the Strawberry Creek weir (4,870 g) and from creel samples (5,540 g) decreased from 2006, and were much lower than long term averages (weir average  $7,579 \pm 253$  g; creel average  $7,010 \pm 195$  g). Also, the standard weight index in 2007 (3,830 g) decreased from 2006 and was near the lowest for the time series (average standard weight 4,249  $\pm$  37 g). Except for the level I trigger for age-2 Chinook salmon from the survey, all growth indices triggered both level I and II flags in 2007.

**Ration and forage:** Trends for the index of ration (grams of total prey in stomach) also suggest that food availability for Chinook salmon has declined in recent years, with a slight temporary improvement in 2006. For most age classes of Chinook salmon, ration was low in 1998, increased for several years following the exceptionally strong 1998 year-class of alewife, and declined substantially from 2002-2005 (Figure 7).

Figure 7. Amount of prey consumed

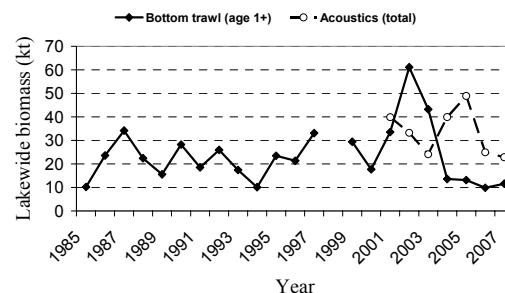


Average ration for 1990-2007 was  $15.8 \pm 1.5$  g and  $24.1 \pm 1.8$  g for age 2 and 3 Chinook salmon, respectively (Table 1). In 2007, ration was similar to the long-term average at 18.6 g for age-2

and below average at 22.8 g for 3 year olds. Both indices triggered level II red flags in 2007.

Estimates of forage fish biomass are reported in kilotonnes (kt; 1 kt = 1,000 metric tons) of age-1 and older alewife from bottom trawl surveys and in kt of total alewife biomass from acoustic surveys (Figure 8). Average biomass from bottom trawl surveys is  $23.1 \pm 2.3$  kt, ranging from 9.8-61.1 kt during 1985-2007 (Table 1). The alewife biomass in 2007 (11.6 kt) was very low, but up slightly from 2006 (the lowest value in the time series). Alewife biomass from acoustic surveys averaged  $33.4 \pm 3.8$  kt, ranging from 22.3-48.9 kt from 2001-2007. Alewife biomass estimated from acoustic surveys decreased in 2007 (22.9 kt). Both bottom trawl and acoustic estimates of alewife biomass triggered level I and level II red flags in 2007.

Figure 8. Lakewide alewife biomass



**Fish health:** Fish health has been monitored using several tests (e.g. visual signs, FELISA, QELISA, DFAT) for the presence of *Renibacterium salmoninarum*, the causative agent for bacterial kidney disease (BKD). Stress-mediated diseases such as BKD can have strong regulatory influences on Chinook salmon populations. Additionally, using consistent methods, gross clinical (visual) signs of disease have been

recorded for fish captured in the open-water survey and for weir returns. On average, about  $51.5 \pm 3.7\%$  and  $94.9 \pm 1.0\%$  percent of fish show no visual signs of disease in open-water surveys and weirs, respectively (Table 1). The number of Chinook salmon showing signs of disease from both data sources have declined through time. In 2007, however, the percent of “healthy fish” (not showing any visual signs of diseased) decreased slightly for the survey (96.4%) and weir (97.7%), but are still at very low levels with less than 4% of fish showing any visual signs of disease (Figures 9 and 10).

Figure 9. Visual signs of disease from spring survey

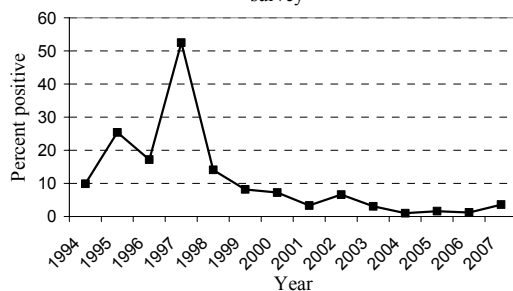
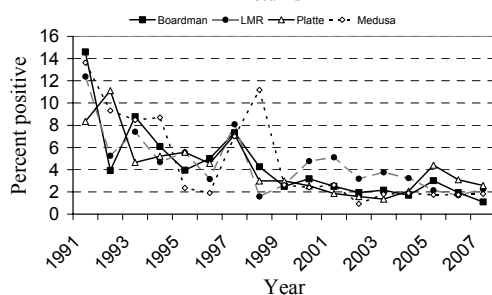


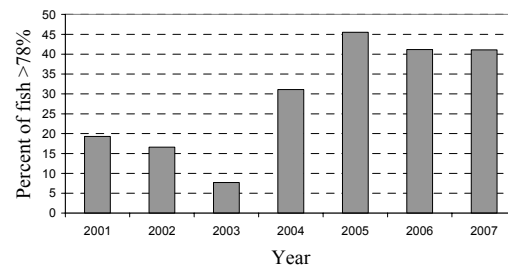
Figure 10. Visual signs of disease from weir returns



Percent water in the body muscle can be used to evaluate changes in fat reserves, another indicator of Chinook salmon health. Laboratory and field studies have been used to establish a level of 78% water in the muscle as an indicator of insufficient fat reserves. Percent water results from 2001-2007 suggest that Chinook salmon in Lake Michigan

may have entered into a period with very low energy reserves (Figure 11). Of the fish health indices evaluated, only percent water triggered a level II red flag in 2007.

Figure 11. Percent of Chinook salmon above 78% water (high water = low fat)



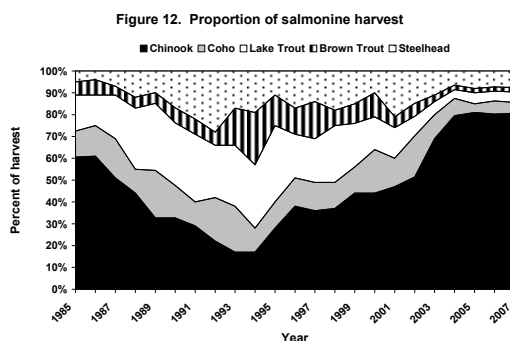
## Summary

Chinook salmon stocking rates (e.g., 1999 and 2006) have been adjusted through a cooperative process in an attempt to minimize the risk of a lakewide population crash and its effects on the fishery. Stocking reductions were based on a review of biological indicators from the SWG and reflected the consensus of managers from each agency involved in stocking. To assist in this management process, the SWG is committed to including new indicators (e.g., the recently-established percent water index) and continuing the ongoing collection and consolidation of lakewide time series data on salmonines in Lake Michigan.

Chinook salmon harvest in 2004-2007 was above the established reference level set forth in the Salmonine Objective for Lake Michigan (3.1 million kg - 6.8 million pounds; Figure 1). Our analysis of the Red Flag parameters suggests that this harvest level is not sustainable and declines in fishery catch rates and harvest levels in the near future are expected. Frequency

distributions of the selected parameters indicated that 41% (7 of 17) triggered Level I red flags. For Level II, 88% (15 of 17) of the parameters indicated red flags. Many of the variables (e.g., growth, ration, forage abundance) have been trending downward, which accounts for the increase in level II red flags.

Our evaluation suggests that we are likely not meeting the Salmonine Objective of the FCOs in two ways. First, we are not maintaining predators in Lake Michigan at levels where predator consumption does not threaten food web integrity. Recent declines in forage fish abundance and Chinook salmon growth indicates that predator consumption has been high relative to supply of prey. Second, proportional harvest of Chinook salmon relative to the other salmonines has been higher than recommended in the FCOs (total harvest of 2.7 to 6.8 million kg, of which 20-25% is lake trout; Figure 12).

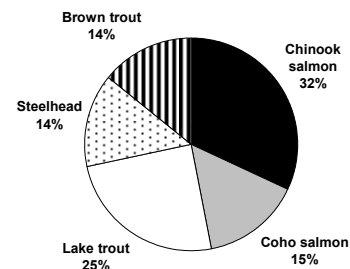


Based on our evaluation of progress toward meeting the salmonine objective, and because over 50% of the level II red flag indicators were triggered in 2007, the SWG recommends to the Lake Michigan Committee (LMC) that additional revisions to salmonine management should be taken to bring a better balance between predator and prey levels.

## Recommendations

Lakewide Chinook salmon stocking was reduced in the spring of 2006 by 25%. Current stocking rates are now at 1978 levels (Figure 1) and Chinook salmon stocking is approximately 1/3 of the salmonine stocking composition for Lake Michigan (Figure 13).

Figure 13. Proportion of lakewide salmonine stocking (based on the number of fish stocked in 2006)



The effect of the 2006 stocking reduction will not be fully realized until that year-class is fully recruited to the fishery. Therefore, managers should consider the latent impacts of the 2006 Chinook salmon stocking reduction, and stocking of other salmonines, when evaluating SWG recommendations and future changes in salmonine management. Moreover, we recommend that managers consider the implications of level I indicators (changes in the recent year) compared to level II (trend indicators for the last five years) on their management options. The results of the 2007 analysis suggests that conditions did not change dramatically from 2006 to 2007, but rather that conditions have been trending downward and have remained outside of the “acceptable” range for several years. Even so, we have observed high catch rates and high harvest levels for several years; likely resulting from a few, strong alewife year-class events (e.g., 1998, 2002, 2005) followed by increased predator



biomass and high expectations for a strong fishery. However, if predator-prey levels are continually out of balance, the greater the likelihood that this could result in long-term negative impacts on the fishery and the Lake Michigan food web. Therefore, we recommend that the Lake Michigan Committee consider modifying salmonine management either through (and not limited to) changes in fishing regulations to increase salmonine mortality rates (i.e., increase bag limits), additional reductions in Chinook salmon stocking levels, or reductions in stocking levels of all salmonines.

### **Future Direction**

The abundance of naturally-produced salmon has been identified as a key uncertainty in the management of Lake Michigan salmonines, especially for Chinook salmon. Starting with the 2006 year-class, all Chinook salmon stocked in Lake Michigan were marked, the majority using oxytetracycline (OTC). In response to a formal charge from the LMC, the SWG report this year includes estimates of natural reproduction which are the results of the SWG's OTC monitoring plan (Claramunt et al. 2007) that was implemented in 2007. Marking of all Chinook salmon stocked into Lake Michigan will continue through the 2010 year-class.

Also in 2007, the Quantitative Fisheries Center (QFC) at Michigan State University responded to a request from the Lake Michigan Committee to update the Lake Michigan Decision Analysis for assessing relative risk of various salmonine stocking strategies. The QFC, in coordination with the SWG, is

pursuing funding to work with fishery managers and key stakeholders to develop an updated decision model to assess the performance of alternate policies for stocking of salmonines in Lake Michigan. In addition to assisting with updating the decision model with existing data, there is a desire to expand it to include all stocked salmonine species. The SWG will be working to consolidate information on the other salmonines, and incorporate the trends in their population characteristics in the Red Flags approach.

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- Eshenroder, R. L., M. E. Holey, T. K. Gorenflo, and R. D. Clark, Jr. 1995. Fish-community objectives for Lake Michigan. Great Lakes Fishery Commission Special Publication 95-3.
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Table 1. Selected red flag variables; data in this summary table were collected during the period 1985-2007.

Biological Variable	Min	Max	Mean	SE	2007	Current Year		Three Out of Five Years	
						Level I	Level I	Level II	Level II
					Values	<20 or >80%	Red Flag	<40 or >60%	Red Flag
<b>Abundance</b>									
Harvest (kg x 1 million)	0.64	4.74	2.26	0.28	3.67	<0.97 or >3.90	No	<1.40 or >2.40	Yes*
Catch Rate (n per 100 hrs)	1.3	16.0	6.4	1.0	16.0	<2.8 or >11.9	Yes*	<4.2 or >6.0	Yes*
Survey (gill net CPE)	1.42	4.48	2.57	0.25	2.11	<1.7 or >3.8	No	<2.1 or >2.3	Yes
SCAA Estimate (n x 1 million)	7.20	13.66	10.53	4.24	NA	<8.75 or >12.66	NA	<9.87 or >11.01	NA
<b>Natural Reproduction</b>									
Percent unmarked (OTC)	23.0	65.8	43.3	4.4	53.5	<31.0 or >53.8	No	<37.9 or >48.0	Yes*
Clip ratio (Obs. Vs. Exp.)	0.17	1.00	0.41	0.1	0.30	<0.25 or >0.57	No	<0.34 or >0.42	Yes
Smolt estimates (n per stream)	5,400	389,317	142,504	24,430	NA	28,297 or 280,000	NA	85,000 or 119,000	NA
Total Recruits (n x 1 million)	6.9	11.1	8.2	0.2	6.9	<7.2 or >9.0	Yes*	<7.6 or >8.4	Yes*
<b>Growth Indices</b>									
Survey weight-at-age 2 (g)	1,692	4,049	2,357	104	2,047	<1,894 or >2,642	No	<2,191 or >2,495	Yes*
Weir weight-at-age 3 (g)	4,870	9,900	7,579	253	4,870	<6,400 or >9,120	Yes	<7,000 or >7,700	Yes
Creel weight-at-age 3 (g)	5,367	8,479	7,010	195	5,540	<6,187 or >7,838	Yes*	<6,671 or >7,451	Yes*
Standard weight (g)	3,814	4,585	4,249	37	3,830	<4,131 or >4,404	Yes	<4,204 or >4,313	Yes
<b>Ration and Forage</b>									
<b>Abundance</b>									
Ration age 2 (g)	6.4	32.1	15.8	1.5	18.6	< 7.8 or >19.6	No	<14.5 or >17.4	Yes*
Ration age 3 (g)	8.9	38	24.1	1.8	22.8	<19.8 or >30.1	No	<22.8 or >25.0	Yes*
Bottom trawl (kt)	9.8	61.1	23.1	2.3	11.6	<12.5 or >33.3	Yes	<17.8 or >23.6	Yes
Acoustic biomass (kt)	22.3	48.9	33.4	3.8	22.9	<23.6 or >43.5	Yes	<26.6 or >38.6	Yes*
<b>Fish Health</b>									
Visual Signs – Survey (% w/o)	47.5	99.0	51.5	3.7	96.4	<82.9	No	<91.8	No
Visual Signs - Weir (%w/o)	87.6	98.4	94.9	1.0	97.7	<92.6	No	<94.8	No
Percent Water Index (>78%)	7.7	45.5	28.9	5.5	41.1	>42.9	No	>39.1	Yes*
Weir DFAT: Strawberry Creek	0	67	10.8	3.7	NA	>15.0	NA	>6.8	NA

\* = A change in the Red Flag from the 2006 (survey year) assessment. NA = data not available.